Research Report

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ASSESSMENT AND MITIGATION OF POTENTIAL ENVIRONMENTAL IMPACTS OF PORTLAND CEMENT CONCRETE HIGHWAY GRINDINGS

by

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16. ABSTRACT

The primary objectives of this study were to quantify the affect of PCC slurry on roadside soil pH and to evaluate the effectiveness of using compost to at least partially neutralize slurry pH. Soil pH as a function of depth was determined along known areas of slurry disposal (I-90 and SR-195). Soil metal concentrations (cadmium, copper, lead and zinc) and soil calcium concentrations were also determined. Slurry pH neutralization tests were performed by blending compost (from two different sources) with PCC grinding slurry at three slurry:compost ratios and monitoring pH as a function of time. Roadside soil pH was shown to be significantly elevated in some areas along SR-195 and slightly elevated in some of the I-90 sampling locations. Compost was shown to reduce slurry pH from about 12 to as low as 8.6 for a slurry:compost ratio of 5:1 (w/w). No significant difference between background soil metal concentrations and those in impacted areas was observed.

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EXECUTIVE SUMMARY

Cooling water used during the diamond grinding of Portland Cement Concrete (PCC) highways generates a high pH and high alkalinity slurry consisting of water, concrete and aggregate residue. In eastern Washington, this slurry is deposited along the highway shoulder during grinding operations. Concern has been expressed regarding the impact of grinding slurry on soil pH. And, since WSDOT uses significant quantities of compost as a soil-amending agent, questions were posed regarding the usefulness of compost as an effective pH neutralization agent. Consequently, the primary objectives of this study were to quantify the affect of PCC slurry on roadside soil pH and to evaluate the effectiveness of using compost to at least partially neutralize slurry pH. Soil pH as a function of depth was determined along known areas of slurry disposal (I-90 and SR-195). Soil metal concentrations (cadmium, copper, lead and zinc) and soil calcium concentrations were also determined. Elevated calcium concentrations relative to background levels were used as an indicator of the presence of slurry since calcium is a major component of Portland Cement Concrete. Slurry pH neutralization tests were performed by blending compost (from two different commercial sources) with PCC grinding slurry at three slurry:compost ratios and monitoring pH as a function of time.

The pH of the soil in the non-impacted area on SR-195 was in the range 6.3-7.5. On the other hand, the pH of the soil in the slurry disposal area ranged from 7.6-9.4 with a mean value of 8.2, indicating that the soil pH in the receiving area is elevated relative to background and that the impact on soil pH remains after at least seven years (grinding and slurry disposal conducted in 1997). Soil pH within the slurry disposal area on I-90 was in the range 7.1-8.2 (mean pH = 7.8) while the soil in the non-impacted area ranged from 7.1-7.2. The difference between background and impacted areas along I-90 is not as significant and for the SR-195 site, which may be a result of the longer elapsed time since disposal (grinding conducted in 1992, 1993 and 1997 and soil testing for this project occurred in 2004), and/or the higher rainfall relative to the SR-195 site, but could also be the result of the slurry being disked or plowed into the soil after discharge along the roadside, an activity that occurred at the I-90 site, as reported by WSDOT personnel.

No differences in soil metal concentrations between background and slurry-impacted sites were observed at either SR-195 or I-90 locations. As is typically seen in

areas receiving highway runoff, soil metal concentrations were greater for surface samples compared to samples collected at depth. The observed concentrations were also shown to be in ranges typically found in soils.

Compost was effective at reducing slurry pH. A slurry:compost ratio of 10:1 (w/w) resulted in a pH reduction from about 12 in the raw slurry to 10.9 or 10.4, depending upon the type of compost used. At a ratio of 5:1 the final pH was 8.2 and 8.0 for the two composts that were evaluated. Decreasing the slurry:compost ratio further did not result in further pH reduction under the conditions studied. Per lane mile compost requirements to reduce grinding slurry pH from about 12 to 8 was estimated to be 194 yd^3.

INTRODUCTION

The U.S. public road system contains over 2000 km^2 of Portland Cement Concrete (PCC) surfacing, which constitutes about 6 percent of all paved public roads (Slater, 1995). Often, PCC highways are rehabilitated by diamond grinding and/or the addition of dowels between slab joints to improve highway smoothness and longevity. The Washington State Department of Transportation (WSDOT) is the first state DOT to undertake dowel retrofitting on a large scale to extend the service life of some of the state's 30-year-old concrete highways by 10 to 15 years. Both of these rehabilitation activities generate PCC slurry, a result of the use of cooling water during the cutting and grinding processes. The slurry typically consists of fine stone, cement and other materials washed from the pavement. For most Washington operations, the slurry percent solids content ranges from 5% to 15%. It is interesting to note that in other states, the solids content is about 50 %. This greater water content of slurry generated in Washington is a result of harder aggregates and a slower grinding rate, resulting in the use of more cooling water per m^2 of resurfaced highway.

In areas where grinding slurry cannot be disposed of along the roadside, contractors often partially neutralize the slurry supernatant after settling with liquid acid or by bubbling CO_2 until a desired pH is achieved. In eastern Washington, slurry is deposited along the roadside without pH adjustment. And, although studies suggest that the presence of toxic compounds are generally well below concentrations of concern, elevated slurry pH levels will likely increase soil pH. The degree of impact of grinding slurry on soil pH has not been defined, however. Consequently, The primary objectives of this investigation, therefore, were to define the impact of PCC highway grinding slurry on soil pH in disposal areas and investigate a potentially efficient and affordable method to neutralization slurry pH prior to or during disposal using compost.

LITERATURE REVIEW

Regardless of the slurry solids content, the pH of cooling water slurry is elevated, with reported pH values between approximately 9 and 13 (Diamond Surface Inc., 2004: Holmes & Narver, 1997). Studies have also focused on defining and quantifying constituents of concern such as toxic metals and volatile organic compounds (VOC) present in grinding slurries. The International Grooving and Grinding Association (IGGA) performed an analysis on grinding slurries generated during three resurfacing projects (International Grooving and Grinding

Association, 1990). Two samples were obtained from different locations on a highway grinding project in Delaware, three samples were taken from different locations on an interstate highway grinding project in Pennsylvania, and two samples were taken from different locations on a bridge deck grinding project in South Carolina. The objectives of the analyses were to define specified inorganic and organic slurry constituents and compare to maximum permissible limits for each component as established by the U.S. Environmental Protection Agency and the North Carolina Department of Environment, Health and Natural Resources (Table 1). The study did not, however, report slurry pH. The report concluded that the grinding slurry was non-ignitable, non-corrosive and non-toxic and considered a non-hazardous waste under the criteria for identifying hazardous waste under the Code of Federal Regulations (Code of Federal Regulations, 2003).

Table 1. Analysis of grinding slurry from three project sites. Concentrations reported in mg/kg (International Grooving and Grinding Association, 1990).

Constituent	Sample Number							Maximum Concentration Limit	
	1	2	3	4	5	6	7	EPA	NC
Arsenic	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<5.00	<0.50
Barium	0.8	1.1	0.96	2.1	2	1.65	1.8	<100	<10.00
Cadmium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<1.00	<0.10
Chromium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<5.00	<0.50
Lead	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<5.00	<0.50
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.20	<0.02
Selenium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<1.00	<0.10
Silver	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<5.00	<0.50
Copper	3.1	1.6	1.7	2.6	3.15	2.1	1.85	NA	NA
Zinc	2.6	2.9	1.65	2.65	2.8	1.76	1.9	NA	NA
Aluminum	6570	6900	8210	7420	6840	7250	9130	NA	NA
Benzene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01
Toluene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.06	<0.01
Ethyl Benzene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.08	<0.01
Xylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.08	<0.01
Gasoline	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.00	<0.10
Fuel Oil	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.00	<0.10
Diesel Fuel	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.00	<0.10
Lube Oil	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.00	<0.10

Holmes and Narver (1997) prepared one of the most comprehensive reports on the analysis of concrete grinding residue associated with the grinding operation of roadway surfaces. Samples were analyzed for a wide range of organic and inorganic constituents, including toxicity testing (Appendix A). In addition to the slurry samples, fresh water used for grinding operation was also sampled to assess any potential impact of fresh water quality on the properties of the waste slurry. Prior to analysis, each slurry sample was separated into solid (sludge) and aqueous phases (supernatant) by gravity settling. In addition to constituent analysis, a 96-hour Acute Toxicity test was conducted which showed no toxicity characteristics for the slurry samples as manifested by the 100 % survival rate of the test fish (fathead minnows). It should be noted that a study of leachate prepared from PCC highway material (not grinding slurry itself) exhibited moderate to high toxicity, which was attributed to undefined inorganic compounds. It was also determined that the toxicity was negligible after the leachate passed through a one-meter soil column (Nelson et al., 2001). Another study that evaluated the long-term leaching of toxic trace metals from PCC found that of the ten toxic metals analyzed, only vanadium was at detectable limits and only in “poorly cured” PCC; all metals were below method detection limits in well cured PCC (Hillier et al., 1999).

The Holmes and Narver study found that VOCs in both the slurry solids and supernatant were below the detection limit, with the following exception (Appendix A). In slurry supernatant samples S001 and S004 benzene was detected, but at levels below the Title 22 California Code of Regulations (CCR) and California Drinking Water Standards. In slurry supernatant sample, S006 the benzene concentration of 0.0011 mg/L was below the Title 22 standard (0.5 mg/L) but slightly exceeded the California Drinking Water Standard (0.001 mg/L). Toluene was detected in slurry supernatant samples S001 (0.00078 mg/l), S002 (0.00057 mg/L), S003 (0.00063 mg/L), and S005 (0.00071 mg/L). Toluene concentrations were all well below the California Drinking Water Standard (0.15 mg/L). No ethyl benzene, xylene, chlorinated pesticides or herbicide concentrations were detected in any of the slurry supernatant or settled sludge samples.

The analysis of semi-volatile compounds indicated the presence of benzoic acid in all slurry supernatant samples. The benzoic acid concentrations ranged from 0.065 mg/L to 0.760 mg/L. The only other semi-volatile compound detected was phenanthrene in solid sample S003 (0.43 mg/L). All slurry samples (solid and slurry supernatant) showed concentration levels for oil and grease and total petroleum hydrocarbon (TPH) above detection levels. TPH levels were between 7.9-29.0 mg/L for the slurry supernatant and 16.0-62.0 mg/Kg for solid samples. For slurry supernatant and settled sludge samples, oil and grease concentrations ranged between 3.5-19.4 mg/L and 54.0-640.0 mg/Kg, respectively. Title 22 metals analyses indicated concentrations of barium, copper, and chromium present in all slurry supernatant and settled sludge samples at levels below the corresponding Title 22 standards. Detectable concentrations of other metals such as antimony, arsenic, cobalt, lead, molybdenum, nickel, selenium, vanadium, and zinc were present in only a few slurry supernatant and settled sludge samples. Cadmium was present in only one sample (slurry supernatant S002). Concentrations for beryllium, mercury, silver, and thallium were below detection limits in all slurry supernatant and settled sludge samples.

Metal concentrations in a limited number of samples exceeded the California Drinking Water Standards. For the non-Title 22 metals (aluminum, magnesium, silica, iron, and calcium) analyzed in the slurry supernatant samples, concentrations of aluminum exceeded the California Drinking Water standard (1 mg/L) in samples S002 (30.2 mg/L), S005 (2mg/L), and S006 (3.4 mg/L). Iron concentrations in slurry supernatant samples S002 (25.5 mg/L), S005 (1.72 mg/L), and S006 (3.15 mg/L) were higher than the California Drinking Water Standard.

With respect to anionic constituents in the slurry supernatant samples; the sulfate concentrations in all samples were higher than the California Drinking Water standard. Sulfate concentrations ranged between 376 mg/L (S003) and 611 mg/L (S004). Nitrite/Nitrate concentrations exceeded the California Drinking water Standard (10 mg/L) for slurry supernatant samples S001 (17.5 mg/L), S004 (12.5 mg/L), S005 (13.0 mg/L), and S006 (14.5 mg/L). Total cyanide concentrations in all slurry supernatant samples were significantly lower (0.02-0.03 mg/L) than the California Drinking Water standard (10 mg/L) for slurry supernatant samples S001 (17.5 mg/L), S004 (12.5 mg/L), S005 (13.0 mg/L), and S006 (14.5 mg/L). Total cyanide concentrations in all slurry supernatant samples were significantly lower (0.02-0.03 mg/L) than the California Drinking Water standard (0.2 mg/l). COD values in the slurry supernatant samples ranged between 252 mg/L and 985 mg/L. TDS concentrations varied between 1310 mg/l and 2490 mg/L. TSS concentrations ranged from less than 20 mg/L to 122 mg/L (for the supernatant).

PROJECT OBJECTIVES

The findings obtained from the literature review suggest that additional data should be collected regarding the impact of Portland cement concrete grinding slurry on soil pH in the receiving area compared to non-impacted soils. Since it is believed that the greatest potential for negative environmental impact may be pH related due to both high pH and alkalinity of grinding slurries, the study also focused on developing a mitigation strategy that would include an evaluation of using compost to neutralize the alkaline pH of grinding slurry. The primary objectives of this investigation, therefore, were to define the impact of PCC highway grinding slurry on soil pH in disposal areas and investigate efficient and affordable methods to neutralization slurry pH prior to or during disposal. Metal concentrations in the roadside soils were also evaluated since the high dissolved solids concentration as well as pH in PCC slurry may impact soil metal concentration profiles. The objectives were met by performing the following specific project tasks.

1. In concert with WSDOT personnel, sampling sites were defined in eastern and western Washington where roadside slurry disposal occurred.

2. Soil samples were collected from selected locations at each site as a function of depth, including samples from non-impacted areas.

3. Each soil sample was analyzed for soil pH and the concentration of copper (Cu), cadmium (Cd), lead (Pb), zinc (Zn) and calcium (Ca) was determined.

4. Slurry was collected from two grinding operations and used in a series of pH neutralization experiments using compost from the WSU compost facility and a local commercial compost production operation.

EXPERIMENTAL METHODS

Sampling Sites and Collection Methods

Soil samples were collected from three grinding projects that occurred along I-90 and one project on SR-195 (Table 3). Background samples as each site were selected at locations a reasonable distance outside of the region of highway where grinding took place. The samples were collected at the same distance from the highway as the samples collected within the impacted area. Samples were collected from the surface at intervals of 10 cm to a depth of approximately 30 cm when conditions permitted. In many cases, the actual depths (as reported in following figures and tables) were not in exact 10 cm increments due to rock layers. A shovel was used for collection (rinsed with deionized water (DI) water between sample sites) and samples were placed in Ziploc bags, labeled, and stored on ice for transport to the laboratory. Soil samples were also collected in the non-impacted areas at each sample site and used as background samples. Slurry samples were collected from the SR-195 project, the Starbird Road project and the Bellingham project; no soil samples were collected from the later two projects, however.

The two composts used for the neutralization of PCC grinding slurry were obtained from the Washington State University Compost Facility and EKO compost, produced in Lewiston, ID and obtained from a local garden and landscaping shop (EKO Compost, 2002: Washington State University, 2003). Compost properties, supplied by the manufacturers are listed in Table 2.

Table 2. Washington State University compost and EKO compost properties. Information supplied by manufacturer.

Washington State University Compost	EKO Compost
Source Materials	
Animal manure and bedding - 78% Coal ash - 10% Processed compost - 10% Food waste - 1% Green house soil and potting plant material - .5% Yard waste - .5% Shredded wood waste (added during wet seasons to increase porosity) - .5%	Green and brown wood products (leaves, limbs, lawn clippings, wood chips, Christmas trees) and biosolids.
Reported Parameters	
pH: 8.0 - 9.1***** Electrical conductivity (EC): 2 - 7 mhos/cm Organic carbon: 25 - 31% (organic matter, 45 - 56%) Organic nitrogen: 0.8 - 1.1% C:N ratio: 30 to 35:1 NH4+-N: 5 - 25 ppm NO3--N: 25 - 50 ppm Available P: 30 - 100 ppm Available K: 2500 - 6500 ppm	PH: 8.6****** Organic Matter: 44% Organic nitrogen: 2.3% Phosphorus: 1.9% Potassium: 1.8% Moisture Content: 44%

***** Using the standard procedure in our laboratory (presented below), the pH was determined to be 8.0

** Using the standard procedure in our laboratory (presented below), the pH was determined to be 7.1

The bulk density of the compost was measured by weighing know volumes and taking an average, with a result of 625 lb/yd^3.

Soil pH Determination

The pH of all soil samples was measured using the saturated paste procedure. Approximately 20-25 g of soil was placed in a plastic beaker and deionized water (DI) water was slowly added. The soil was stirred frequently during DI water addition and stopped when a shiny, glistening surface was obtained on the soil. The beaker was tapped a few times on the table to expel air and then allowed to sit for approximately two minutes. Additional DI water was added if the surface no longer glistened. Soil was added if there was standing water. The consistency of soil was such that it flowed slightly. The saturated paste was then allowed to stand for 35-40 minutes and centrifuged to obtain a clear supernatant. A calibrated pH (Fisher Accumet) meter and electrode was then placed in the clear supernatant and the pH reading was recorded.

Table 3. WSDOT grinding projects where soil sampling occurred.

Highway	Project Name	Project Year
I-90	Kachess River to Yakima River	1992
I-90	Easton Hill to Yakima River	1993
I-90	Hyak Vicinity to Ellensburg-Phase1	1997
SR-195	Bridge 195/34 to Bridge 195/38	1997

Soil and Slurry Analyses

The soil samples were analyzed for metals by the acid digestion procedure (USEPA, 1994). For the determination of total recoverable analytes in soil samples, the soil sample was mixed thoroughly and a portion of the sample (>20g) was transferred to a tared weighing dish. The sample was weighed and the wet weight (WW) was recorded. For samples with <35 % moisture a 20 g portion was sufficient. For samples with moisture >35%, a larger aliquot (50-100g) was required. The sample was dried to a constant weight at 60°C and the dry weight (DW) of the sample was recorded. The sample was dried at 60°C to minimize the loss of mercury and other volatile metallic compounds, to facilitate sieving, and to ready the sample for grinding. The dried sample was sieved using a No.5-mesh polypropylene sieve to remove large objects and gently ground using a mortar and pestle. From the dried, ground material an accurately weighed (1.0 ±0.01 g) representative aliquot (W) of the sample was transferred to a 250-mL beaker for acid extraction. To the beaker, 4mL of 1:1 reagent grade HNO_3 and 10 mL of 1:4 of reagent grade HCl were added. The beaker was covered with a watch glass and placed on a hot plate for reflux extraction of the analytes. The hot plate was located in a fume hood and previously adjusted to provide a reflux temperature of approximately 95°C.

The sample was heated and gently refluxed for 30 minutes. Under proper conditions gentle boiling occurs, however vigorous boiling was avoided to maintain an azeotropic mixture. The sample was allowed to cool and the extract was transferred to a 100-mL volumetric flask. The extract was diluted with DI water to the 100 mL mark and the contents mixed thoroughly. The diluted extract solution was allowed to stand overnight, filtered and stored at 4°C and prior to analysis. Copper, cadmium, lead and zinc were quantified by inductively coupled argon plasma mass spectrometry (ICP-MS, HP 4500 Plus). Calcium, used as an indicator of the presence of PCC slurry, was quantified by inductively coupled argon plasma optical emission spectrometry (ICP-OES, Perkin-Elmer Optima 3200RL). The slurry samples, cuttings and paste material were also analyzed for metal concentrations. Prior to analysis, the slurry sample was separated into solid and aqueous phases (slurry filtrate) by filtration. The solid material retained was dried and extracted for total metals using the procedure detailed above.

Calibration Standards and Sample Blanks

Mixed calibration standards of 25 mg/L, 50 mg/L and 100 mg/L were prepared by combining the appropriate volumes of the metal stock solutions in 1-L volumetric flasks. The stock solutions were separately analyzed for possible spectral interference. Calibration standards were verified for stability by using quality control standards.

Three types of blanks were used in this method. A calibration blank was used to establish an analytical calibration curve, the laboratory reagent blank was used to assess possible contamination from the sample preparation procedure, and a rinse blank was used to flush the instrument uptake system and nebulizer between standards, instrument performance check solutions and samples to reduce memory interferences. Instrument performance check solutions were prepared using method analytes in the same acid mixture as the calibration standards and were used to evaluate the performance of the instrument system.

The Method Detection Limits (MDL) for the metals analyzed for are presented in Table 4. MDL is the minimum concentration of an analyte that can be identified, measured, and reported with 99% confidence that the analyte concentration is greater than zero.

Alkalinity and Total Suspended Solids

Slurry alkalinity and total suspended solids was determined by procedures outlined in Standard Methods (Standard Methods, 1995).

Table 4. Total recoverable metals method detection limits (MDL)

Analytes	MDL* (mg/Kg)
Copper	0.5
Cadmium	0.2
Lead	2
Zinc	0.3
Calcium	2

*Estimated based on aqueous phase MDL determinations

Slurry pH Neutralization Experiments

Grinding slurry collected from the resurfacing sites at SR-195, the Starbird Road project and the Bellingham project was blended with WSU and EKO compost over a range of slurry:compost ratios (10:1, 5:1 and 1.3:1 (w/w)). However, only the SR-195 slurry neutralization results are presented in this report, as these slurry samples were completely mixed prior to collection and represent slurries that would be discharged on roadsides in eastern Washington. After blending slurry and compost, the pH of the mixture was monitored as a function of time. If the slurry-compost ratio was such that no free liquid was present (the 1.3:1 experiments), DI water was added to a small sub-sample of the slurry - compost mixture and the pH of the extract was measured. Initial neutralization experiments were carried out with 5 L of slurry, while latter experiments used 100 mL slurry volumes. Initial slurry pH was measured in all experiments; pH was monitored in a blank slurry sample (no compost) for selected experiments.

RESULTS AND DISCUSSION

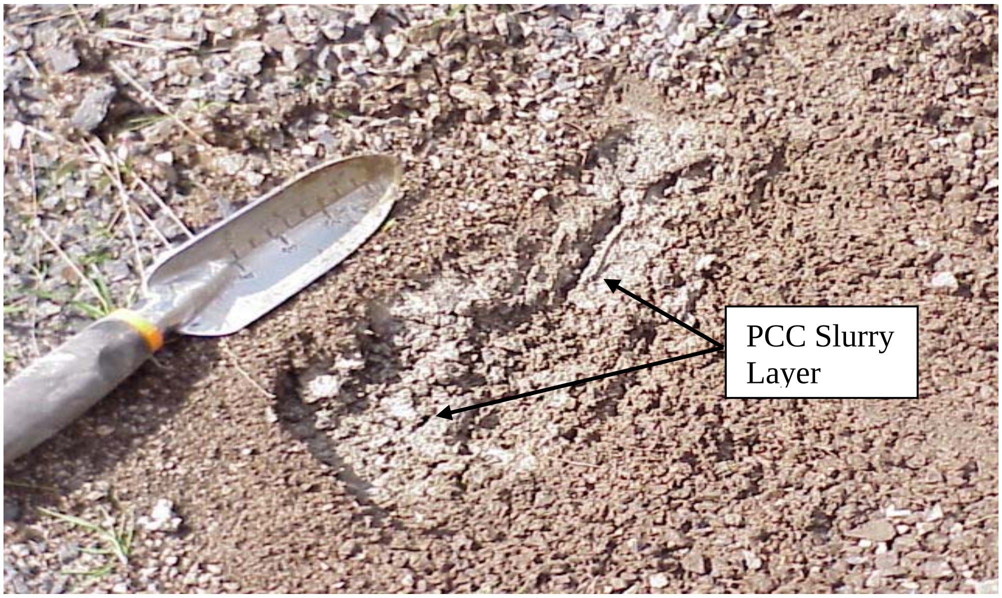
Sampling was initiated on SR-195 with a site field trip to obtain general information (soil type, areas of standing water, define background sample locations, etc.) project area. Visual observations did indicate the presence of what appeared to be a layer PCC material a few cm below the surface in some of the roadside sites (Figure 1). This observation was not made at all sites investigated, so it was decided to determine soil calcium concentration as an indicator of the presence of slurry. Subsequent analysis did confirm that the material was most likely PCC based on the high calcium concentrations relative to soil below the layer and values in the background samples.

4.1 Soil pH

The pH of the soil in the non-impacted area on SR-195 was in the range 6.3-7.5. On the other hand, the pH of the soil in the slurry disposal area ranged from 7.6-9.4 indicating that the soil pH in the receiving area was elevated relative to background and that the impact on soil pH remains after at least seven years. Soil pH within the slurry disposal area on I-90 was in the range 7.1-8.2 while the soil in the non-impacted area ranged from 7.1-7.2. The difference between background and impacted area along I-90 is not as significant and for the SR-195 site, which may be a result of the longer elapsed time since disposal and/or the higher precipitation relative to eastern Washington, but could also be the result of the slurry being disked or plowed into the soil after discharge along the roadside at the I-90 site, as reported by WSDOT personnel. The grinding slurry in Eastern Washington is deposited along the highway shoulder and is not plowed into the soil.

The data in Figure 2 represent soil pH along SR-195 at each sampling location and as a function of depth. In general, there is no trend in soil pH as a function of depth for the samples collected. Soil calcium concentration was determined as an indicator of the presence of slurry and to confirm that any observed increases in pH were likely a result of the presence of slurry. The data in Figure 3 summarize the soil calcium concentrations for the SR-195 soil samples. The average calcium concentration for samples collected in the disposal area was 11,874 ±4,756 mg/Kg while the average background calcium concentration was 4,971 ±1,545 mg/Kg (95% confidence intervals). A comparison of sample means using the t-test (95% level) indicates that soil calcium concentrations were significantly greater in the impacted verses non-impacted area, confirming that the most likely cause of increasing soil pH is from the presence of PCC slurry. As can be seen, surface samples from site 49b and 49c yielded very high calcium concentrations, indicating that the samples contained part of and existing slurry layer.

Soil pH from sample sites along I-90, just as with SR-195, showed no obvious trend with depth. Although the soil pH values from the impacted area were greater than background, the difference was not as great as was observed for SR-195. Additionally, there was no observed



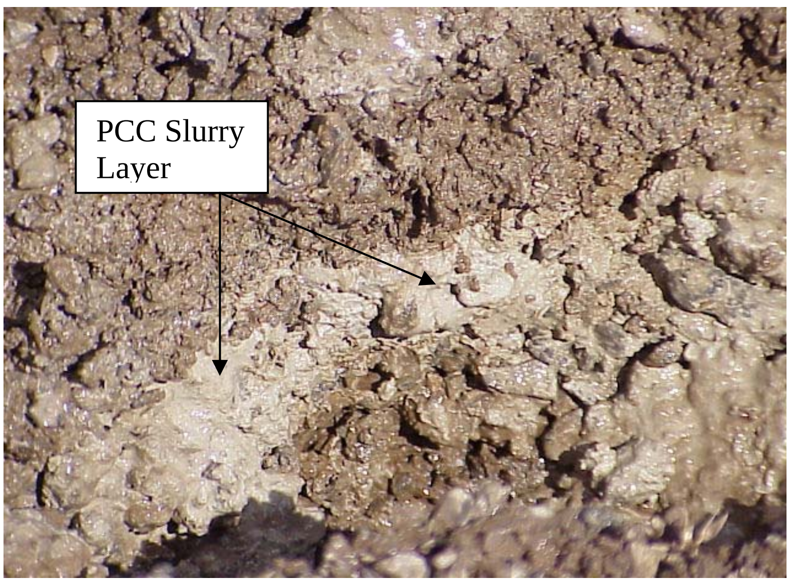


Figure 1. Photographs at two locations along SR-195 showing a layer of PCC slurry (light grey), contrasted with the surrounding soil (brown or darker grey if in black and white).

layer of slurry as was observed at the SR-195 sites. The soil calcium data from I-90 yielded an average value of 5,687 ±877 mg/Kg for the impacted area verses 6,944 ±809 mg/Kg (95% confidence limits), indicating no statistically significant difference between the two sample means. Again, the modest increase in soil pH and similar soil calcium concentrations in the impacted and non-impacted areas are likely a result of tilling the slurry disposal area and the more than ten years that lapsed since disposal.

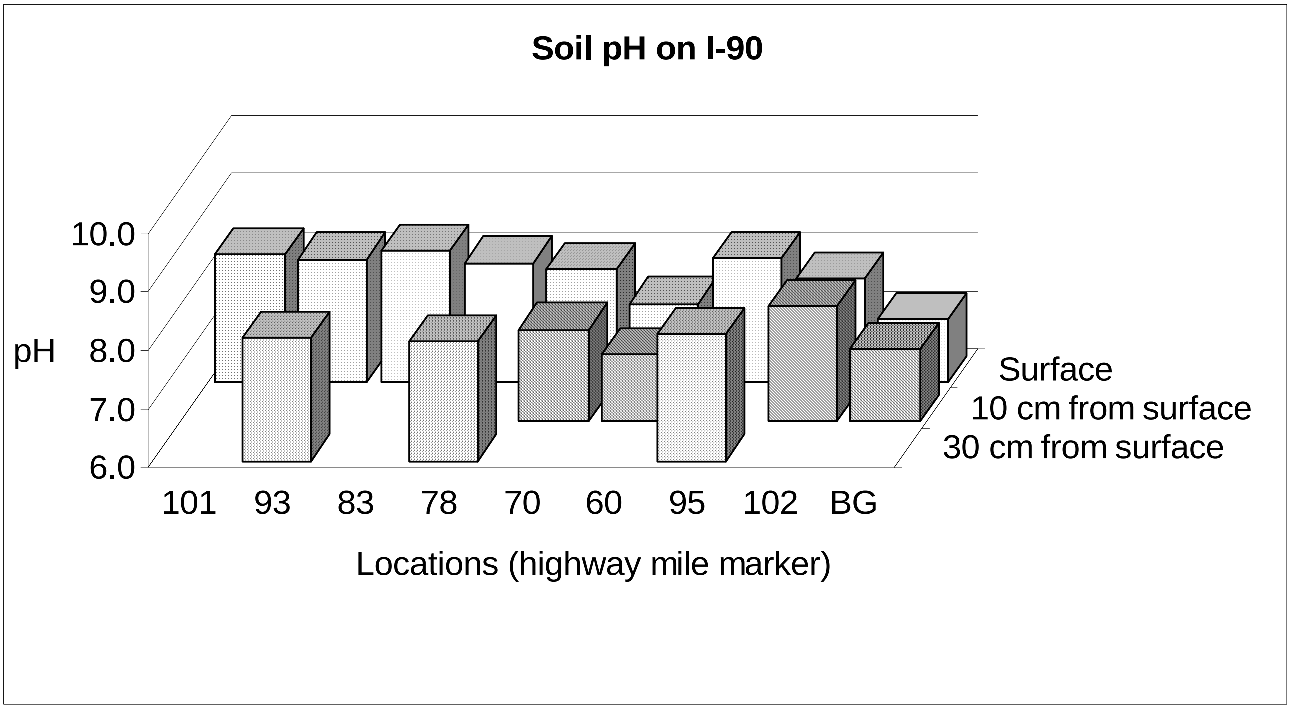


Figure 2. Soil pH at SR-195 sample sites as a function of depth (BG = background sample).

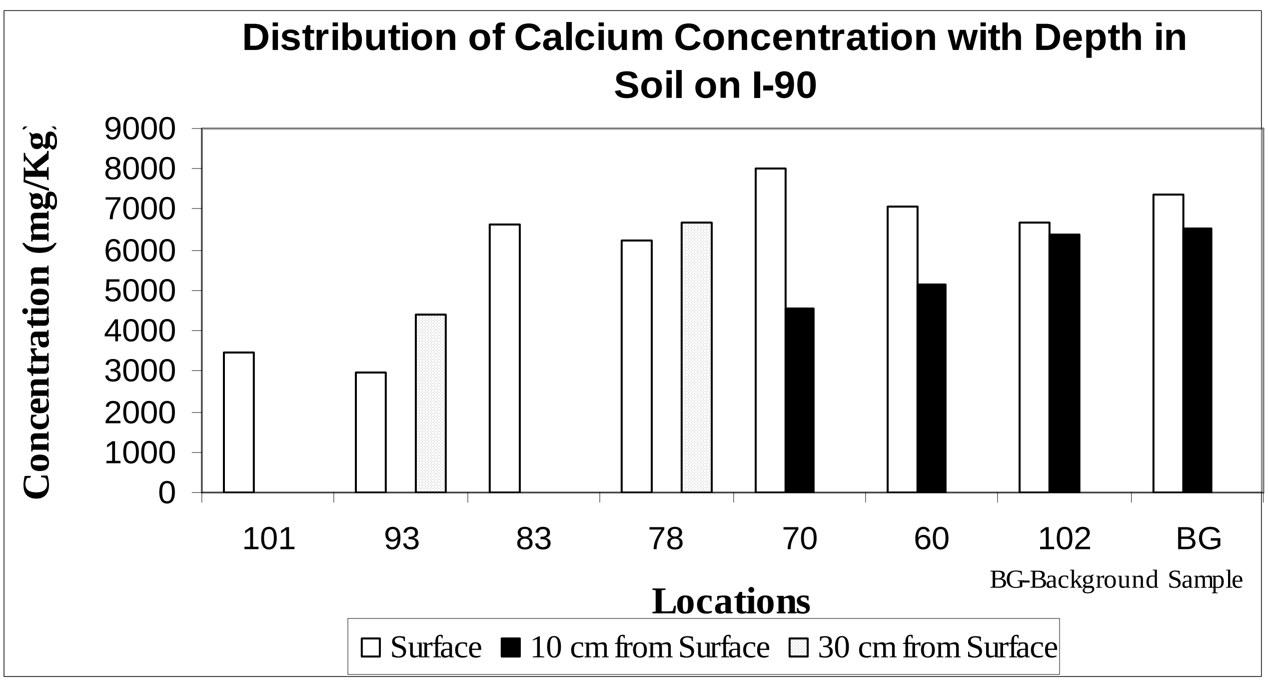


Figure 3. Soil calcium concentrations at SR-195 sample sites as a function of depth (BG = background sample).

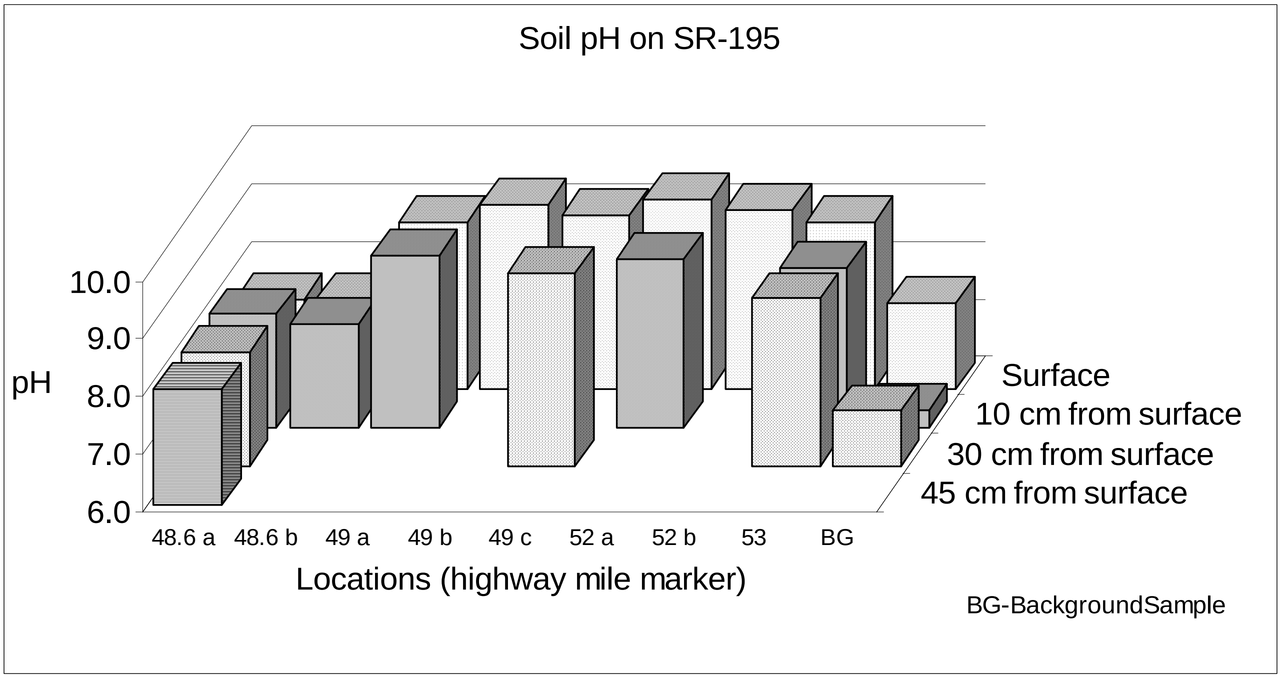


Figure 4. Soil pH at I-90 sample sites as a function of depth (BG = background sample; a, b, and c refer to replicate samples collected within 1 ft. of each other).

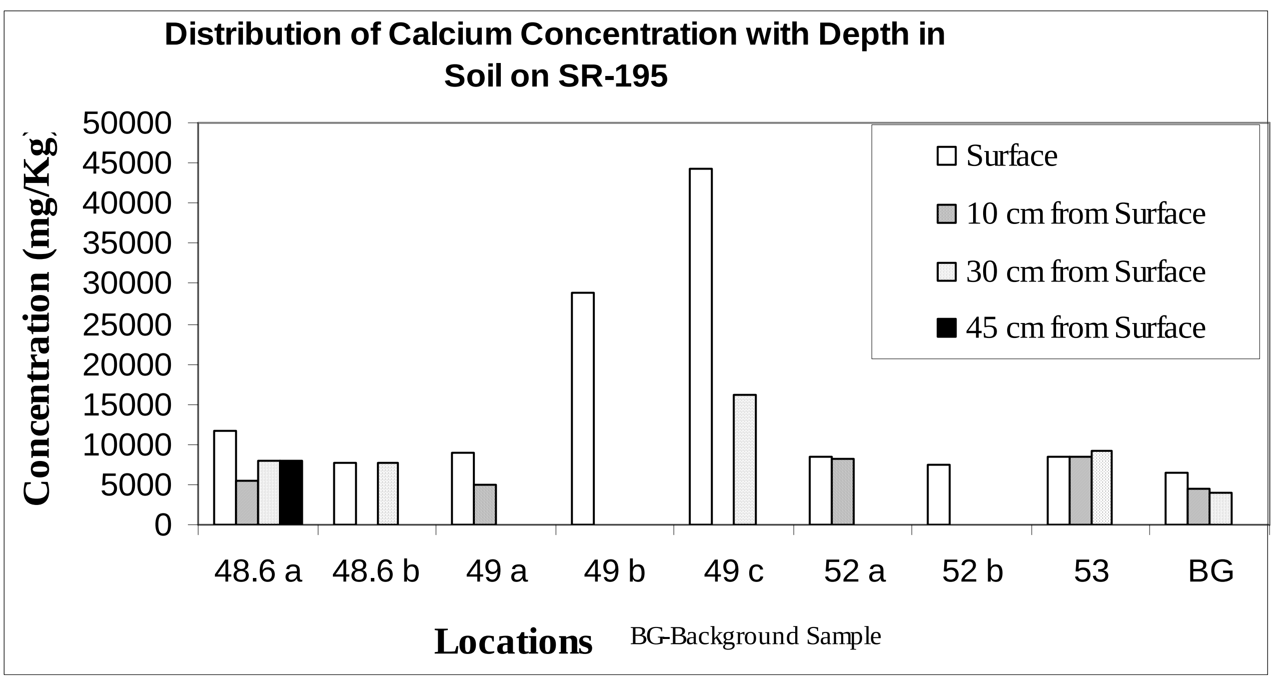


Figure 5. Soil calcium concentrations at I-90 sample sites as a function of depth (BG = background sample; a, b, and c refer to replicate samples collected within 1 ft. of each other).

Soil Metal Concentrations

In general, for those sites along I-90 and SR-195 where samples could be collected as a function of depth, metal concentrations were greatest at the surface and decreased in deeper samples. This is not unexpected as metals have relatively high soil partition coefficients, resulting in slow downward migration. Soil metal concentrations for lead are shown in Figure 6 and Figure 7 and represent the trends observed for copper, zinc and cadmium (Appendix D). It was thought that soil metal concentrations in areas that directly received slurry might be higher than background concentrations due to the greater pH and potential for greater retention due to lower metal solubility and higher partitioning. No significant differences between background soil metal concentrations and those in the slurry disposal areas were observed, however. It addition, it was observed that the soil metal concentrations were within typical ranges of reported values for a wide range of soils (Kabata-Pendias and Pendias, 1984).

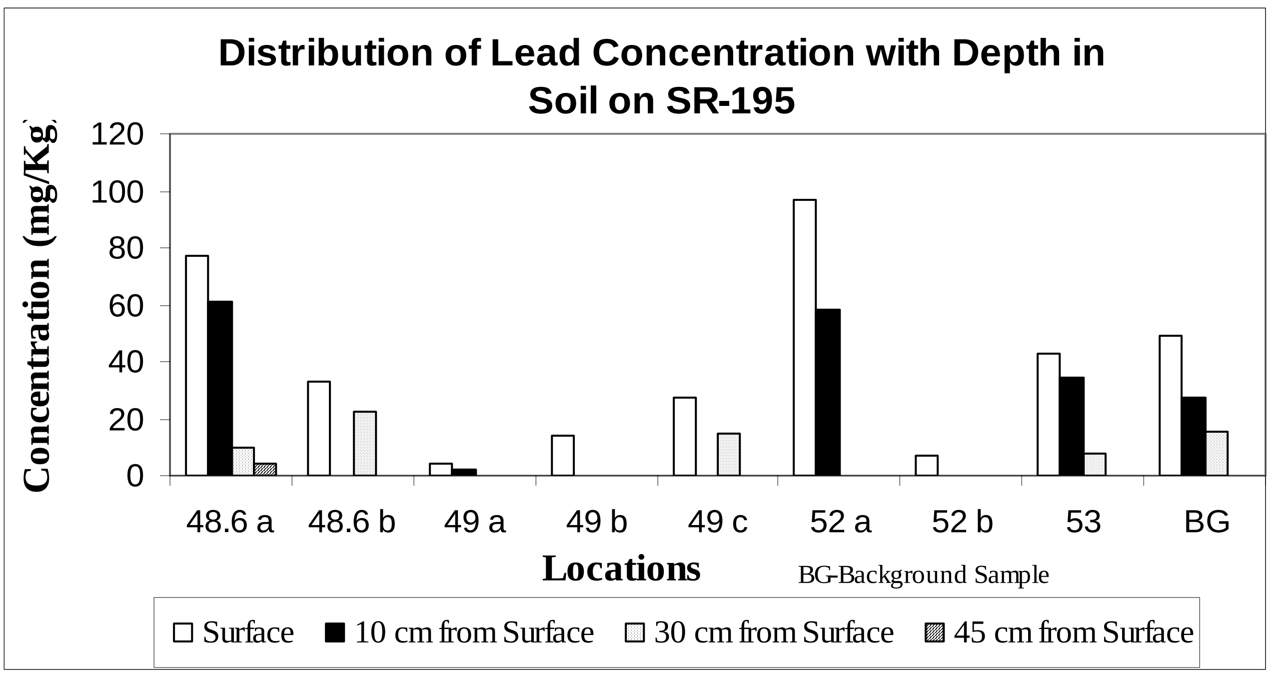


Figure 6. Soil lead concentrations at SR-195 sample sites as a function of depth (BG = background sample; a, b, and c refer to replicate samples collected within 1 ft. of each other).

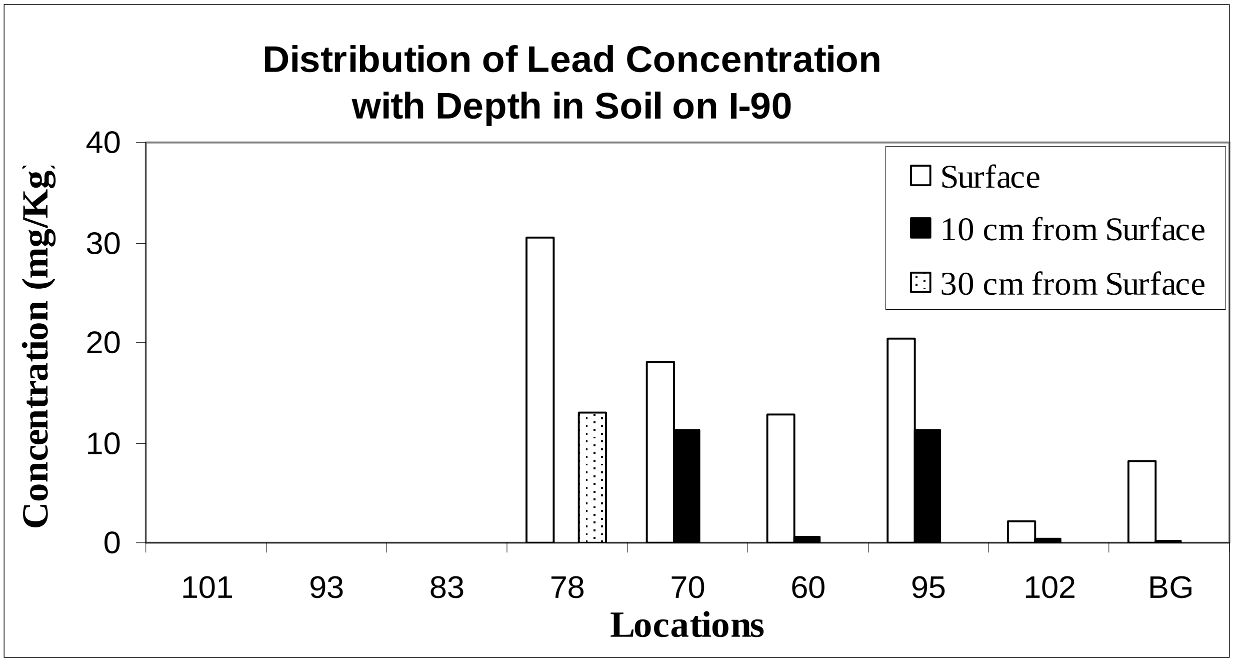


Figure 7. Soil lead concentrations at I-90 sample sites as a function of depth. Concentrations were below detection at 101, 93, and 83 (BG = background sample).

Slurry Neutralization Using Compost

The grinding slurry collected from the SR-195 project was blended with WSU and EKO compost at three slurry:compost ratios, 10:1, 5:1 and 1.3:1 (weight of slurry:weight of compost) and pH was monitored as a function of time. The data in Figure 8 indicate that an immediate drop in pH occurs following the addition of compost to PCC slurry, as the pH is shown to decrease from 12.1 to 10.9 and 10.4 at a slurry:compost ration of 10:1 (w/w) for WSU and EKO composts, respectively. This ratio would correspond to about 1.2 gallons of slurry per pound of compost. Using the measured compost bulk density of 625 lb/yd^3 yields a compost requirement of 1.4 yd^3 per1000 gallons of grinding slurry. A very slight decrease of about 0.1 pH units occurred over the 6.5 hour period of monitoring. The greater pH reduction observed for the EKO compost was a result of the lower compost pH (7.1) compared to the WSU compost (8.0).

The data in Figure 9 show an initial pH drop from 12.1 to 9.0 and 8.6 for WSU and EKO composts, respectively, at a slurry:compost ratio of 5:1. After a 24 hour contact time, the final pH was 8.0 and 8.2 for the EKO and WSU compost, respectively. A third test was performed at a slurry:compost ratio of 1.3:1, which yielded a more solid-like, non-fluid mixture. It can be seen (Figure 10) that no additional pH reduction was observed compared to the 5:1 ratio, indicating that a ratio of 5:1 or less would be adequate for reducing the pH to about 8.0 or 8.2, depending upon the compost used. A 5:1 slurry compost ratio would require 2.7 yd^3 of compost per 1000 gallons grinding slurry.

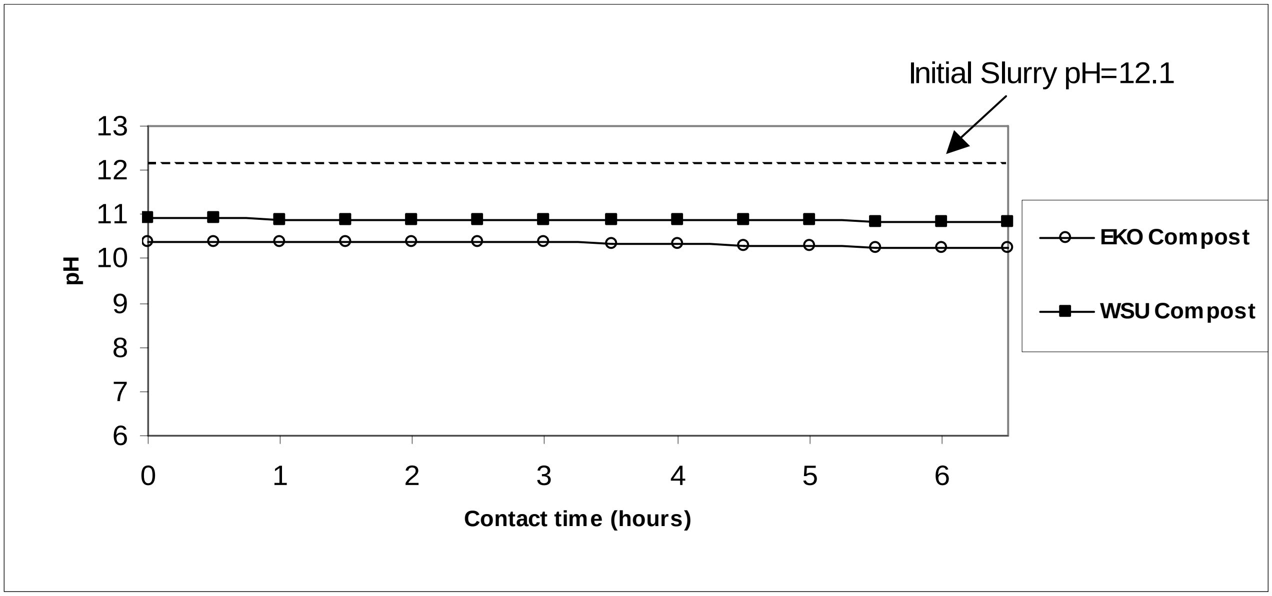


Figure 8. Slurry pH neutralization at a slurry:compost ration of 10:1 (w/w)

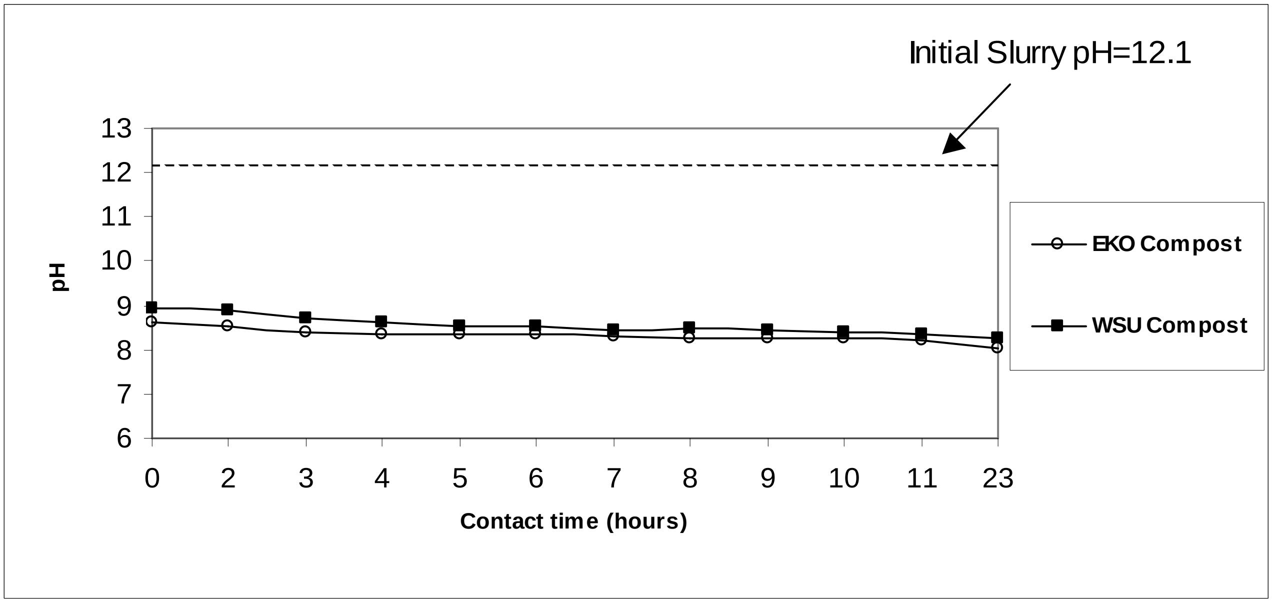


Figure 9. Slurry pH neutralization at a slurry:compost ration of 5:1 (w/w).

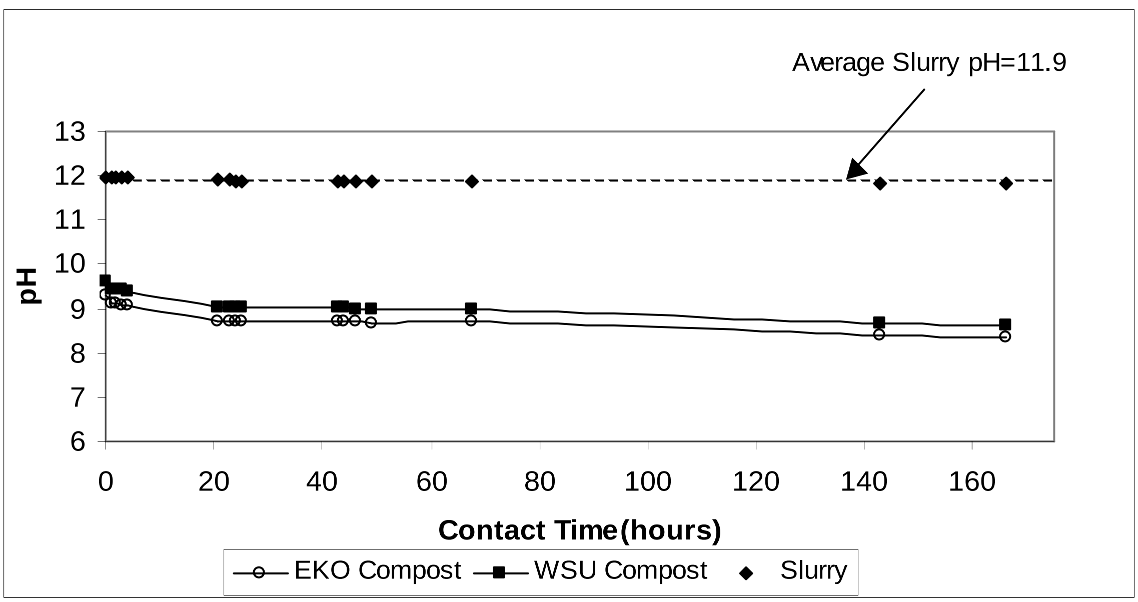


Figure 10. Slurry pH neutralization at a slurry:compost ration of 1.3:1 (w/w).

SUMMARY AND CONCLUSIONS

The results indicate that soil pH was found to be higher in slurry disposal areas in comparison with the non-impacted areas. The pH of the soil in the slurry disposal area on SR-195 ranged from 7.56-9.37 while background pH ranged from 6.3-7.5. Soil pH within the slurry disposal area on I-90 was in the range 7.14-8.24, indicating a moderate increase above the range of pH 7.07-7.23 for background samples. This indicates that slurry application does increase soil pH in the disposal areas. With respect to soil metal concentrations, the concentrations of copper, cadmium, lead and zinc decreased with depth in soil profile. However, no particular trend was observed in the variation of metal concentrations between impacted and non-impacted areas.

Compost was effective at reducing slurry pH. A slurry:compost ratio of 10:1 (w/w) resulted in a pH reduction from about 12 in the raw slurry to 10.9 or 10.4 for WSU and EKO compost, respectively. At a ratio of 5:1 the respective final pH after a 24 hr contact period was 8.2 and 8.0 for WSU and EKO compost. Decreasing the slurry:compost ratio further did not result in further pH reduction under the conditions studied. Therefore, reducing slurry pH from 12 to 10.4 would require about 1.4 yd^3 EKO compost per 1000 gallons of slurry and reducing the pH to 8.0 would require 2.7 yd^3 of EKO compost per 1000 gallons.

Estimates of slurry generation per lane mile were made based on information received from personal communication with Diamond Surface, Inc. An average grinding slurry generation rate is 1,350 gallons per hour and the grinding truck travels about 300 feet per hour, yielding a slurry generation of 4.5 gallons per foot. This is a relatively slow rate of travel but is necessary in Washington State due to the hard aggregate used in the PCC. The truck has to make three passes to complete one 12 ft lane, so the truck travels 1.58×10^4 linear feet to complete one lane mile and generates about 7.2×10^4 gallons of slurry in the process. If one were to use EKO compost and the desire was to reduce slurry pH to 8, about 194 yd^3 of compost would be required per lane mile. From a visual perspective, this volume of compost (5,238 ft^3) could be spread over one mile of highway shoulder in a 1 ft wide by 1 ft high layer.

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APPENDIX A:
CALTRANS PCC GRINDING SLURRY ANALYSIS

Table 5. PCC grinding slurry analysis (Title 22) of the supernatant from settled sludge samples (Holmes & Narver, 1997).

Sample ID	Aluminum	Magnesium	Silica	Iron	Calcium
S001	ND	0.92	38.1	ND	462
S002	30.2	32.6	65.1	25.5	654
S003	ND	6.59	22.7	0.14	207
S004	ND	0.33	32	0.08	335
S005	2	15	27.1	1.72	168
S006	3.4	12.6	30.7	3.15	212

Table 6. Supernatant and settled solids analysis (Title 22 inorganic analytes) (Holmes & Narver, 1997).

Sample ID	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc
S001 supernatant	0.006	0.01	0.1	ND	ND	0.11	ND	0.27	ND	ND	0.05	0.03	0.009	ND	ND	ND	ND
S001 sludge	ND	8.4	190	ND	ND	6.8	2.4	15	6.3	ND	ND	7.9	ND	ND	ND	13.8	28.4
S002 supernatant	0.009	0.03	4.35	ND	0.001	0.11	0.04	0.12	0.046	ND	0.04	0.11	0.004	ND	ND	0.11	0.19
S002 sludge	ND	8.4	224	ND	ND	18.2	4.7	27.1	13.5	ND	ND	18.7	ND	ND	ND	21.8	46.9
S003 supernatant	ND	ND	0.1	ND	ND	0.05	ND	0.06	ND	ND	0.02	ND	ND	ND	ND	0.03	ND
S003 sludge	ND	9.7	166	ND	ND	10	1.7	22.4	9.9	ND	ND	7.7	ND	ND	ND	14.3	33.9
S004 supernatant	ND	ND	0.08	ND	ND	0.07	ND	0.06	ND	ND	0.03		ND	ND	ND	0.04	ND
S004 sludge	ND	8.7	347	ND	ND	18.5	3.2	53.8	11.8	ND	ND	32.5	ND	ND	ND	19.6	37.9
S005 supernatant	0.004	ND	0.08	ND	ND	0.04	ND	0.002	0.002	ND	0.02	0.02	ND	ND	ND	0.04	ND
S005 sludge	ND	2.3	51	ND	ND	8	1.4	3.3	3.3	ND	ND	5.3	ND	ND	ND	16.3	33.1
S006 supernatant	ND	ND	0.1	ND	ND	0.07	ND	0.004	0.004	ND	0.04	0.02	ND	ND	ND	0.04	0.03
S006 sludge	ND	2.7	66	ND	ND	9.7	2.6	5.5	5.5	ND	ND	6.8	ND	ND	ND	17.8	31.6
(mg/L) STLC*	15	5	100	0.75	1	5	80	25	5	0.2	350	20	1	5	7	24	250
(mg/kg),TTLC*	500	500	10,000	75	100	2500	8000	2500	1000	20	3500	2000	100	500	700	2400	5000
California Drinking Water Standards (mg/L)	0.006	0.05	1	0.004	0.005	0.05		1	0.5	0.002		0.1	0.05	0.1	0.002		5

* Title 22 Regulations

STLC Soluble Threshold Limit Concentration

TTLC Total Threshold Limit Concentration

APPENDIX B:
SOIL PH DATA

Soil pH on SR-195

Mile Post	Location	Sample 1	Sample 2	Mean	pH
48.6a	Surface	2.23872E-08	3.3884E-08	2.81358E-08	7.55
48.6a	10 cm from surface	1.1749E-08	9.7724E-09	1.07607E-08	7.97
48.6a	35 cm from surface	0.00000001	1.0965E-08	1.04824E-08	7.98
48.6a	45 cm from surface	8.31764E-09	1.122E-08	9.76891E-09	8.01
48.6b	Surface	1.44544E-08	3.9811E-08	2.71326E-08	7.57
48.6b	30 cm from surface	1.04713E-08	2.138E-08	1.59255E-08	7.80
49a	Surface	1.54882E-09	1.0471E-09	1.29797E-09	8.89
49a	10 cm from surface	1.12202E-09	8.7096E-10	9.96491E-10	9.00
49b	Surface	7.07946E-10	5.2481E-10	6.16377E-10	9.21
49c	Surface	1.04713E-09	8.9125E-10	9.6919E-10	9.01
49c	30 cm from surface	5.62341E-10	3.3113E-10	4.46736E-10	9.35
52a	Surface	5.88844E-10	4.4668E-10	5.17764E-10	9.29
52a	10 cm from surface	1.41254E-09	9.5499E-10	1.18377E-09	8.93
52b	Close to the edge of shoulder	6.60693E-10	9.1201E-10	7.86352E-10	9.10
53	Surface	1.09648E-09	1.4791E-09	1.28779E-09	8.89
53	10 cm from surface	1.51356E-09	1.7783E-09	1.64592E-09	8.78
53	30 cm from surface	1.34896E-09	1.0471E-09	1.19805E-09	8.92

Soil pH on I-90

Mile Post	Location	Sample 1	Sample 2	Mean	pH
101	Surface	7.94328E-09	5.2481E-09	6.59568E-09	8.18
93	Surface	8.91251E-09	7.0795E-09	7.99598E-09	8.10
93	25 cm from surface	6.30957E-09	9.7724E-09	8.04097E-09	8.09
83	30 cm from surface	6.16595E-09	5.4954E-09	5.83068E-09	8.23
78	Surface	1.07152E-08	7.9433E-09	9.32924E-09	8.03
78	30 cm from surface	7.4131E-09	1.1749E-08	9.58104E-09	8.02
70	Surface	1.44544E-08	9.1201E-09	1.17873E-08	7.93
70	10 cm from surface	2.18776E-08	3.3113E-08	2.74954E-08	7.56
60	Surface	7.24436E-08	2.884E-08	5.0642E-08	7.30
60	10 cm from surface	9.12011E-08	5.8884E-08	7.50427E-08	7.12
78	Surface	1.07152E-08	9.3325E-09	1.00239E-08	8.00
78	10 cm from surface	7.4131E-09	5.4954E-09	6.45426E-09	8.19
88	Surface	1.20226E-08	9.5499E-09	1.07863E-08	7.97
88	15 cm from surface	8.91251E-09	7.9433E-09	8.4279E-09	8.07
95	Surface	8.51138E-09	6.6069E-09	7.55916E-09	8.12
95	30 cm from surface	7.58578E-09	6.3096E-09	6.94767E-09	8.16
102	Surface	2.13796E-08	1.4454E-08	1.7917E-08	7.75
102	10 cm from surface	1.1749E-08	1.0233E-08	1.0991E-08	7.96

APPENDIX C:
PH NEUTRALIZATION DATA

Slurry pH Neutralization (10 :1 w/w)

Contact time	WSU	EKO
0	10.92	10.39
0.5	10.91	10.39
1	10.90	10.39
1.5	10.90	10.38
2	10.90	10.38
2.5	10.89	10.37
3	10.89	10.37
3.5	10.89	10.34
4	10.89	10.33
4.5	10.87	10.29
5	10.86	10.27
5.5	10.84	10.26
6	10.84	10.26
6.5	10.83	10.26

Slurry pH Neutralization (5 :1 w/w)

Contact time	WSU	EKO
0	8.95	8.64
2	8.87	8.51
3	8.72	8.41
4	8.61	8.37
5	8.52	8.34
6	8.51	8.33
7	8.46	8.29
8	8.48	8.28
9	8.44	8.28
10	8.38	8.26
11	8.37	8.22
23	8.25	8.02

Slurry pH Neutralization (1.3 :1 w/w)

Contact Time	Slurry	WSU	EKO
0	11.98	9.63	9.32
1	11.98	9.44	9.12
2	11.96	9.42	9.10
3	11.95	9.42	9.09
4	11.95	9.38	9.06
20.5	11.9	9.04	8.73
23	11.9	9.03	8.73
24	11.89	9.03	8.73
25	11.89	9.02	8.72
43	11.89	9.02	8.71
44	11.89	9.01	8.70
46	11.88	8.99	8.69
49	11.88	8.98	8.69
67.5	11.87	8.97	8.70
143	11.83	8.65	8.38
166	11.81	8.63	8.36

APPENDIX D:
SOIL METAL CONCENTRATION DATA AND FIGURES

Soil Copper Concentrations on SR-195

Mile Post	Location	Sample 1 (mg/Kg)	Sample 2 (mg/Kg)	Average Concentration (mg/Kg)
48.6a	Surface	15.23	16.79	16.01
48.6a	10 cm from surface	18.74	13.56	16.15
48.6a	35 cm from surface	16.82	15.24	16.03
48.6a	45 cm from surface	18.61	13.33	15.97
48.6b	Surface	22.09	21.22	21.66
48.6b	30 cm from surface	21.15	20.36	20.76
49a	Surface	10.59	8.57	9.58
49a	10 cm from surface	6.01	9.634	7.82
49b	Surface	18.64	18.64	18.64
49c	Surface	19.83	18.69	19.26
49c	30 cm from surface	3.146	4.766	3.96
52a	Surface	25.86	22.3	24.08
52a	10 cm from surface	24.54	19.79	22.17
52b	Close to the edge of shoulder	25.3	23.27	24.29
53	Surface	27.3	26.96	27.13
53	10 cm from surface	22.24	24.83	23.54
53	30 cm from surface	23.98	23.16	23.57

Soil Zinc Concentrations on SR-195

Mile Post	Location	Sample 1 (mg/Kg)	Sample 2 (mg/Kg)	Average Concentration (mg/Kg)
48.6a	Surface	91.27	96.09	93.68
48.6a	10 cm from surface	84.82	76.58	80.70
48.6a	35 cm from surface	63.29	58.48	60.89
48.6a	45 cm from surface	68.30	45.99	57.15
48.6b	Surface	135.60	130.00	132.80
48.6b	30 cm from surface	117.30	140.60	128.95
49a	Surface	78.91	81.11	80.01
49a	10 cm from surface	50.42	60.42	55.42
49b	Surface	76.07	71.88	73.98
49c	Surface	29.49	45.01	37.25
49c	30 cm from surface	25.34	30.46	27.90
52a	Surface	86.30	92.57	89.44
52a	10 cm from surface	93.55	75.45	84.50
52b	Close to the edge of shoulder	96.12	84.36	90.24
53	Surface	84.53	79.49	82.01
53	10 cm from surface	81.16	81.49	81.33
53	30 cm from surface	79.26	81.26	80.26

Soil Cadmium Concentrations on SR-195

Mile Post	Location	Sample 1 (mg/Kg)	Sample 2 (mg/Kg)	Average Concentration (mg/Kg)
48.6a	Surface	0.58	0.62	0.60
48.6a	10 cm from surface	0.49	0.46	0.48
48.6a	35 cm from surface	0.45	0.42	0.43
48.6a	45 cm from surface	0.36	0.36	0.36
48.6b	Surface	0.54	0.55	0.55
48.6b	30 cm from surface	0.52	0.54	0.53
49a	Surface	0.55	2.09	1.32
49a	10 cm from surface	0.48	1.69	1.08
49b	Surface	0.56	0.99	0.78
49c	Surface	0.47	0.47	0.47
49c	30 cm from surface	0.38	0.39	0.38
52a	Surface	0.58	1.94	1.26
52a	10 cm from surface	0.74	0.61	0.68
52b	Close to the edge of shoulder	0.39	0.35	0.37
53	Surface	0.73	0.56	0.65
53	10 cm from surface	0.57	0.61	0.59
53	30 cm from surface	0.51	0.54	0.53

Soil Lead Concentrations on SR-195

Mile Post	Location	Sample 1 (mg/Kg)	Sample 2 (mg/Kg)	Average Concentration (mg/Kg)
48.6a	Surface	82.07	72.61	77.34
48.6a	10 cm from surface	86.62	36.10	61.36
48.6a	35 cm from surface	5.63	13.51	9.57
48.6a	45 cm from surface	4.37	<0	4.37
48.6b	Surface	31.62	33.95	32.79
48.6b	30 cm from surface	21.81	23.46	22.64
49a	Surface	4.09	<0	4.09
49a	10 cm from surface	<0	2.24	2.24
49b	Surface	14.89	12.84	13.87
49c	Surface	29.79	25.30	27.55
49c	30 cm from surface	14.52	15.30	14.91
52a	Surface	116.30	77.97	97.14
52a	10 cm from surface	73.57	43.26	58.42
52b	Close to the edge of shoulder	7.54	5.86	6.70
53	Surface	51.91	34.36	43.14
53	10 cm from surface	34.26	35.16	34.71
53	30 cm from surface	7.14	8.24	7.69

Soil Copper Concentrations on I-90

Mile Post	Location	Sample 1 (mg/Kg)	Sample 2 (mg/Kg)	Average Concentration (mg/Kg)
101	Surface	BDL	BDL	BDL
93	Surface	BDL	BDL	BDL
93	25 cm from surface	BDL	BDL	BDL
83	30 cm from surface	0.04	0.14	0.09
78	Surface	23.78	23.91	23.85
78	30 cm from surface	17.90	9.99	13.95
70	Surface	33.85	31.54	32.70
70	10 cm from surface	29.74	29.52	29.63
60	Surface	34.04	33.71	33.88
60	10 cm from surface	13.22	10.02	11.62
78	Surface	34.04	29.68	31.86
78	10 cm from surface	30.71	28.60	29.66
88	Surface	1.13	3.17	2.15
88	15 cm from surface	1.01	1.50	1.25
95	Surface	24.35	24.67	24.51
95	30 cm from surface	1.03	0.73	0.88
102	Surface	24.93	22.23	23.58
102	10 cm from surface	9.74	13.02	11.38

Soil Zinc Concentrations on I-90

Mile Post	Location	Sample 1 (mg/Kg)	Sample 2 (mg/Kg)	Average Concentration (mg/Kg)
101	Surface	2.61	2.67	2.64
93	Surface	2.80	1.89	2.35
93	25 cm from surface	1.63	1.33	1.48
83	30 cm from surface	6.98	2.74	7.53
78	Surface	91.30	83.16	87.23
78	30 cm from surface	78.48	61.82	70.15
70	Surface	106.40	112.90	109.65
70	10 cm from surface	80.03	78.42	79.23
60	Surface	128.10	121.80	124.95
60	10 cm from surface	74.96	68.29	71.63
78	Surface	124.60	136.30	130.45
78	10 cm from surface	111.30	99.34	105.32
88	Surface	20.66	37.38	29.02
88	15 cm from surface	15.70	18.93	17.32
95	Surface	76.54	69.58	73.06
95	30 cm from surface	12.94	7.84	10.39
102	Surface	72.30	76.41	74.36
102	10 cm from surface	64.81	66.41	65.61

Soil Cadmium Concentrations on I-90

Mile Post	Location	Sample 1 (mg/Kg)	Sample 2 (mg/Kg)	Average Concentration (mg/Kg)
101	Surface	0.20	0.19	0.19
93	Surface	0.18	0.16	0.17
93	25 cm from surface	0.17	0.17	0.17
83	30 cm from surface	0.17	0.17	0.17
78	Surface	0.52	0.50	0.51
78	30 cm from surface	0.39	0.41	0.40
70	Surface	0.54	0.55	0.55
70	10 cm from surface	0.39	0.44	0.42
60	Surface	0.65	0.63	0.64
60	10 cm from surface	0.50	0.44	0.47
78	Surface	0.74	0.76	0.75
78	10 cm from surface	0.54	0.51	0.52
88	Surface	0.32	0.39	0.36
88	15 cm from surface	0.32	0.34	0.33
95	Surface	0.34	0.33	0.34
95	30 cm from surface	0.34	0.34	0.34
102	Surface	0.41	0.40	0.40
102	10 cm from surface	0.32	0.33	0.33

Soil Lead Concentrations on I-90

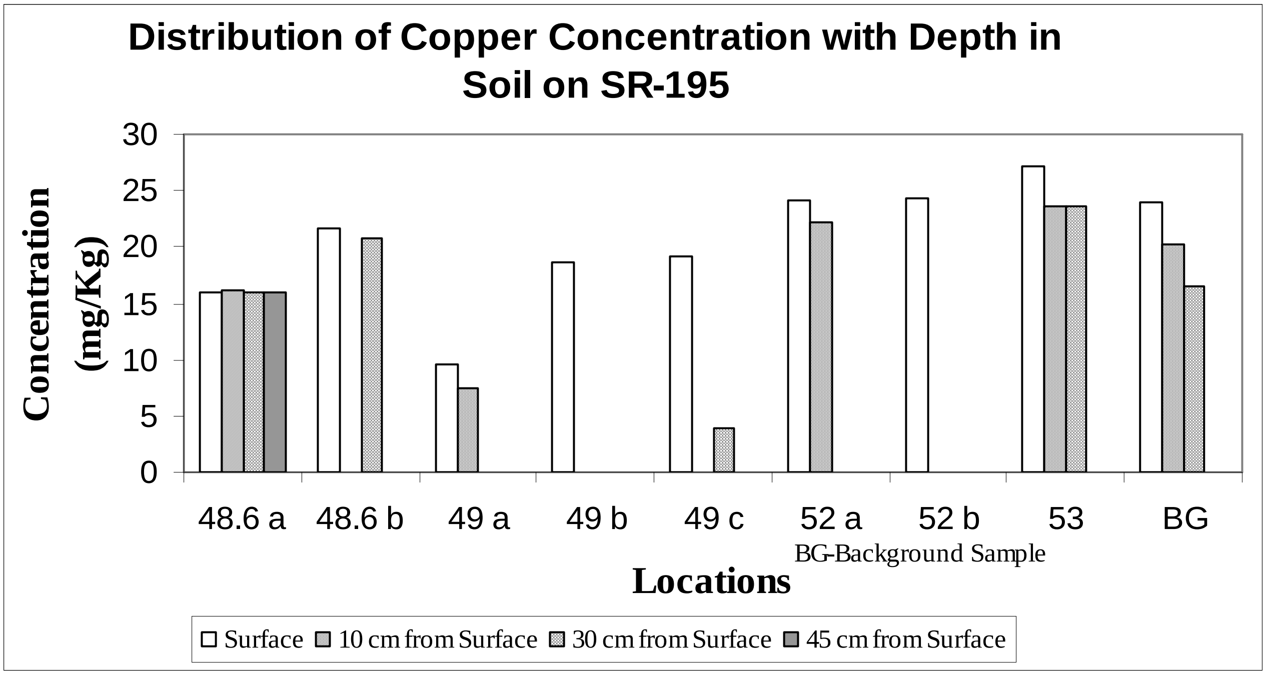
Mile Post	Location	Sample 1 (mg/Kg)	Sample 2 (mg/Kg)	Average Concentration (mg/Kg)
101	Surface	BDL	BDL	BDL
93	Surface	BDL	BDL	BDL
93	25 cm from surface	BDL	BDL	BDL
83	30 cm from surface	BDL	BDL	BDL
78	Surface	43.40	17.40	30.40
78	30 cm from surface	14.03	11.81	12.92
70	Surface	17.19	19.12	18.16
70	10 cm from surface	10.99	11.64	11.32
60	Surface	12.77	12.82	12.80
60	10 cm from surface	0.97	0.21	0.59
78	Surface	82.88	82.76	82.82
78	10 cm from surface	18.94	16.81	17.88
88	Surface	1.28	3.92	2.60
88	15 cm from surface	1.21	3.57	2.39
95	Surface	19.31	21.32	20.32
95	30 cm from surface	10.23	12.47	11.35
102	Surface	2.11	1.97	2.04
102	10 cm from surface	0.47	0.48	0.48

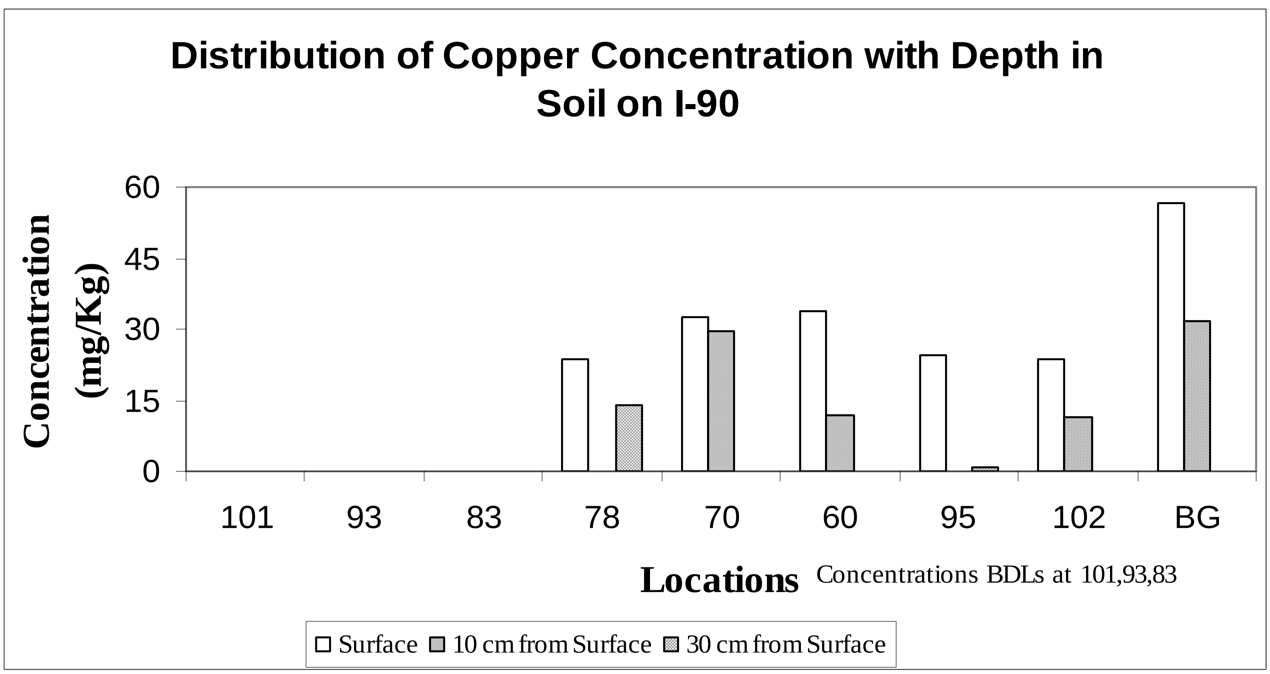
Soil Calcium Concentrations on SR-195

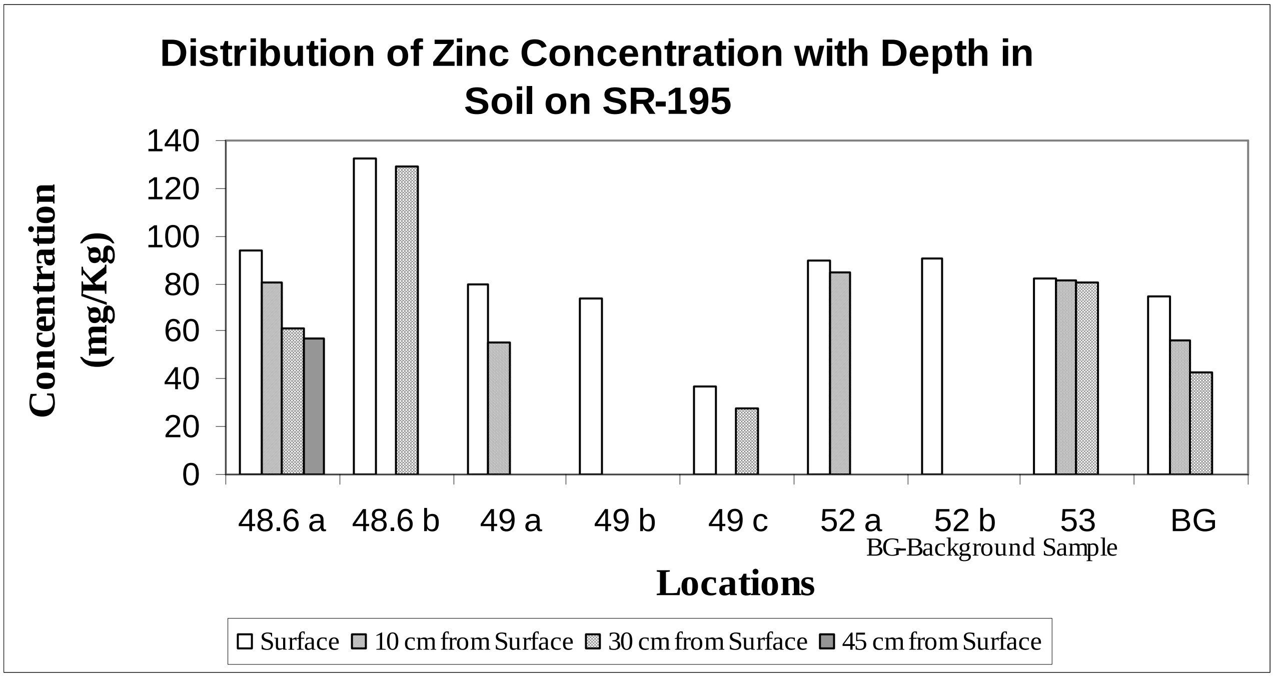
Mile Post	Location	Concentration (mg/Kg)
48.6a	Surface	11704
48.6a	10 cm from surface	5372
48.6a	35 cm from surface	8002
48.6a	45 cm from surface	7865
48.6b	Surface	7759
48.6b	30 cm from surface	7832
49a	Surface	8999
49a	10 cm from surface	4891
49b	Surface	28818
49c	Surface	44378
49c	30 cm from surface	16136
52a	Surface	8395
52a	10 cm from surface	8289
52b	Close to the edge of shoulder	7389
53	Surface	8417
53	About 10 cm from surface	8461
53	About 30 cm from surface	9144

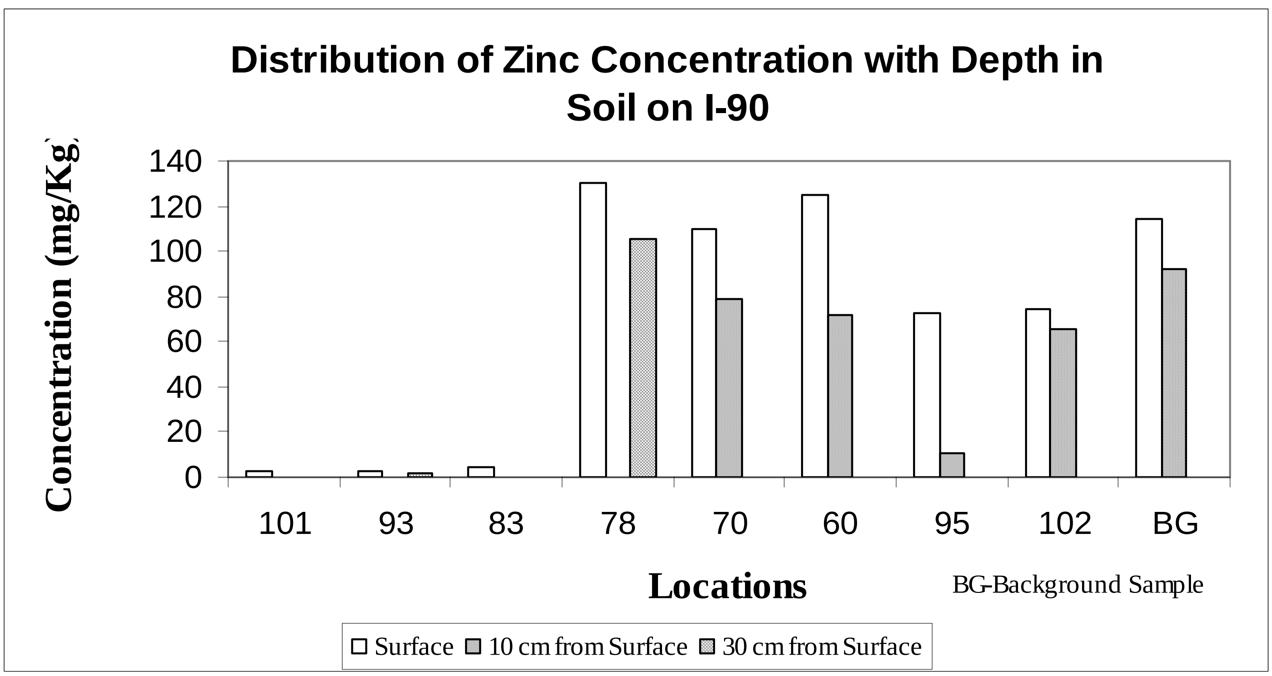
Soil Calcium Concentrations on I-90

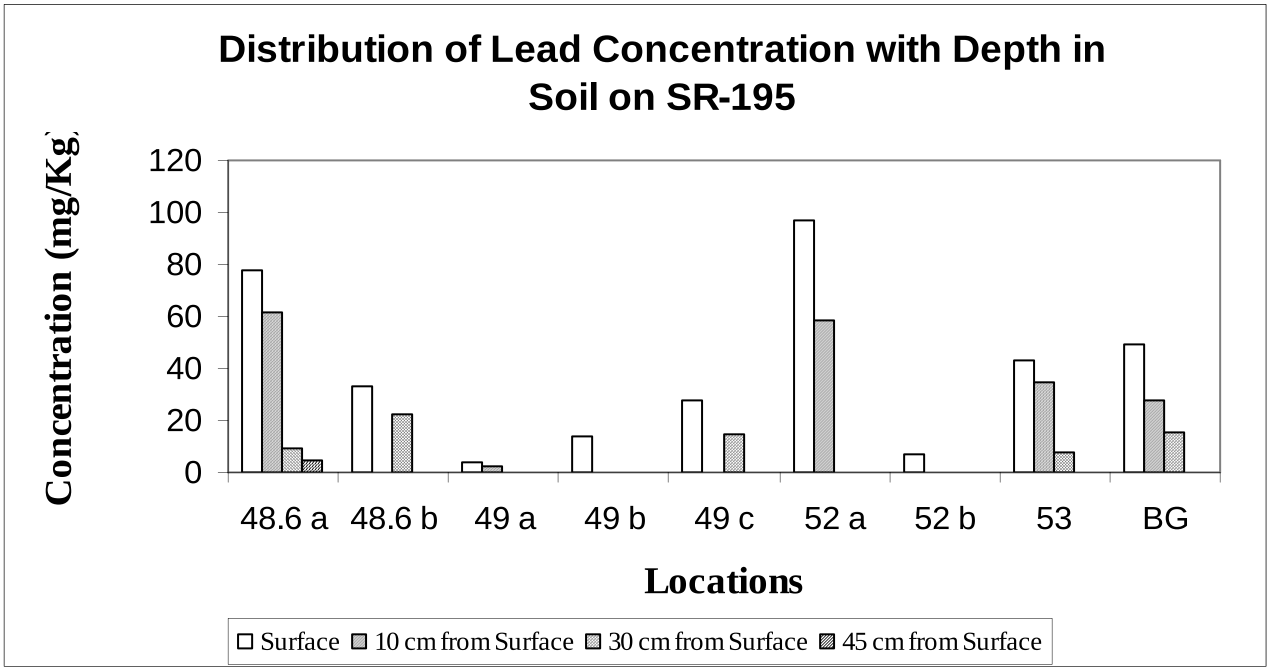
Mile Post	Location	Concentration (mg/Kg)
101	Surface	3482
93	Surface	2983
93	25 cm from surface	4395
83	Surface	6613
78	Surface	6237
78	30 cm from surface	6673
70	Surface	8034
70	10 cm from surface	4546
60	Surface	7081
60	10 cm from surface	5165
102	Surface	6658
102	10 cm from surface	6381


Distribution of Copper Concentration with Depth in Soil on SR-195
Concentration (mg/Kg)
30
25
20
15
10
5
0
48.6 a
48.6 b
49 a
49 b
49 c
52 a
52 b
53
BG
BG-Background Sample
Locations
Surface
10 cm from Surface
30 cm from Surface
45 cm from Surface

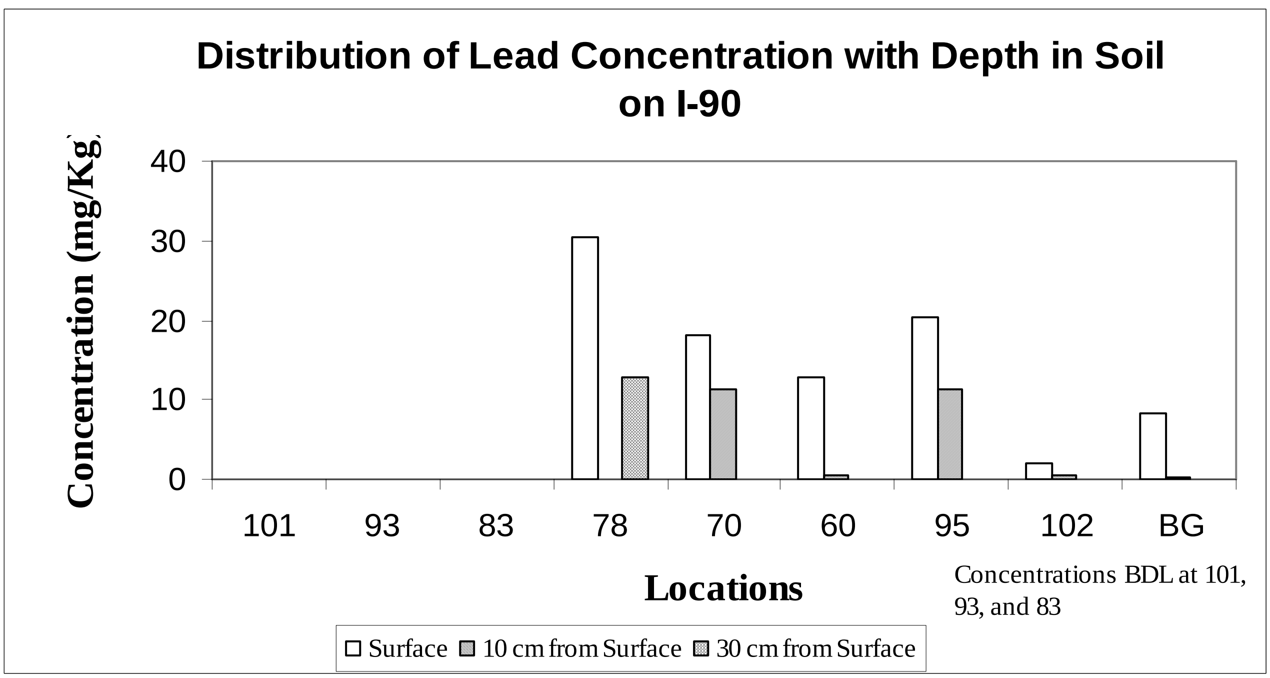

Distribution of Copper Concentration with Depth in Soil on I-90
Concentration (mg/Kg)
60
45
30
15
0
101
93
83
78
70
60
95
102
BG
Locations
Concentrations BDLs at 101,93,83
Surface
10 cm from Surface
30 cm from Surface


Distribution of Zinc Concentration with Depth in Soil on SR-195
Concentration (mg/Kg)
140
120
100
80
60
40
20
0
48.6 a
48.6 b
49 a
49 b
49 c
52 a
52 b
53
BG
BG-Background Sample
Locations
Surface
10 cm from Surface
30 cm from Surface
45 cm from Surface

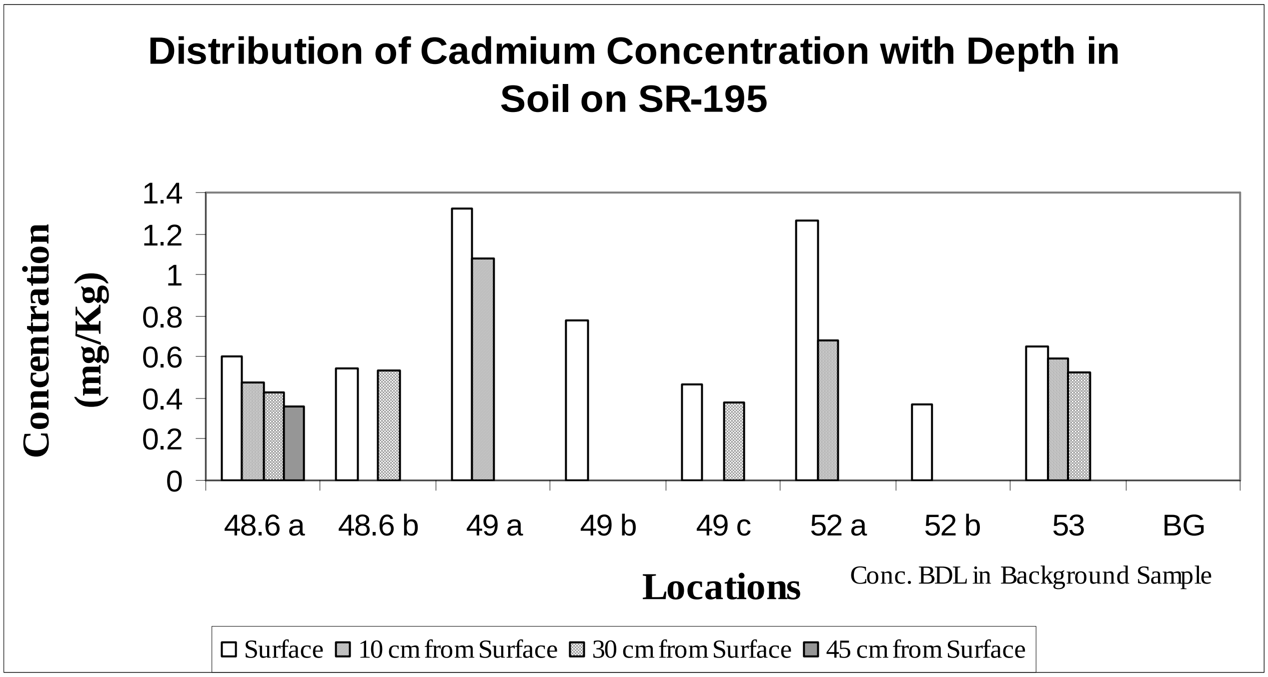

Distribution of Zinc Concentration with Depth in Soil on I-90
Concentration (mg/Kg)
140
120
100
80
60
40
20
0
101
93
83
78
70
60
95
102
BG
Locations
BG-Background Sample
Surface
10 cm from Surface
30 cm from Surface



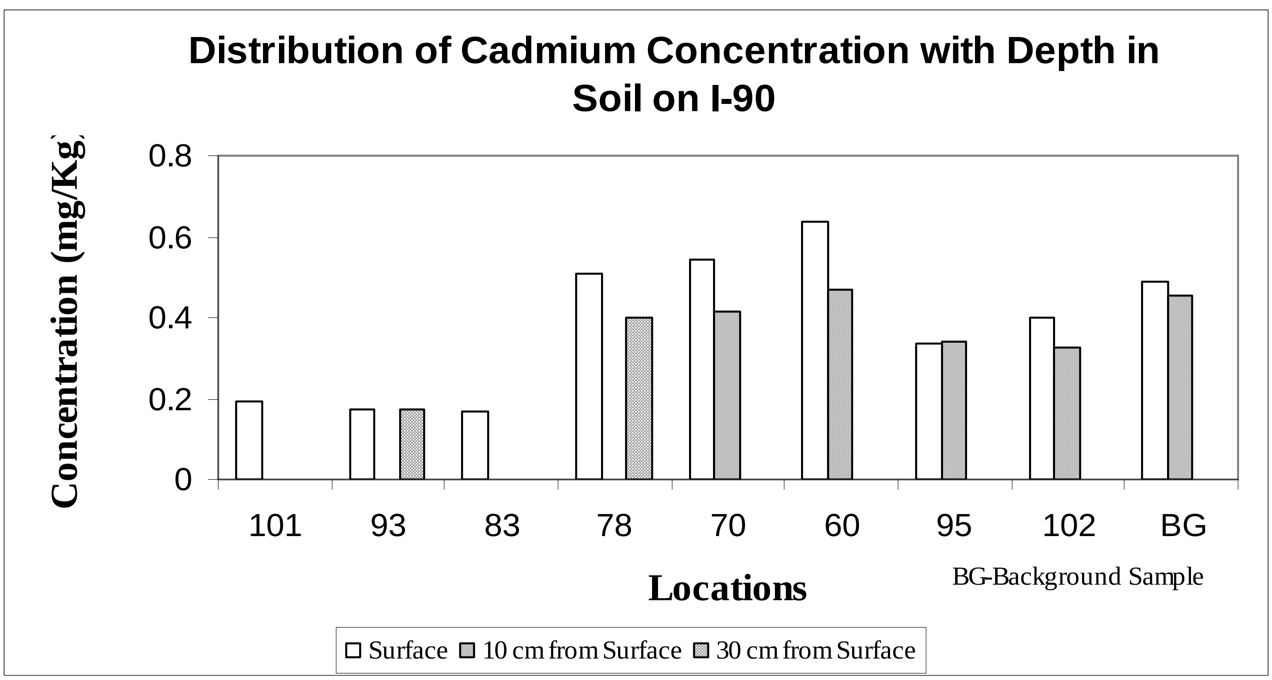
Distribution of Lead Concentration with Depth in Soil on SR-195
Concentration (mg/Kg)
120
100
80
60
40
20
0
48.6 a
48.6 b
49 a
49 b
49 c
52 a
52 b
53
BG
Locations
Surface
10 cm from Surface
30 cm from Surface
45 cm from Surface



Distribution of Lead Concentration with Depth in Soil on I-90
Concentration (mg/Kg)
40
30
20
10
0
101
93
83
78
70
60
95
102
BG
Locations
Concentrations BDL at 101, 93, and 83
Surface
10 cm from Surface
30 cm from Surface



Distribution of Cadmium Concentration with Depth in Soil on SR-195
Concentration (mg/Kg)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
48.6 a
48.6 b
49 a
49 b
49 c
52 a
52 b
53
BG
Locations
Conc. BDL in Background Sample
Surface
10 cm from Surface
30 cm from Surface
45 cm from Surface



Distribution of Cadmium Concentration with Depth in Soil on I-90
Concentration (mg/Kg)
0.8
0.6
0.4
0.2
0
101
93
83
78
70
60
95
102
BG
Locations
BG-Background Sample
Surface
10 cm from Surface
30 cm from Surface

APPENDIX E:
COMPOST AND SLURRY PH AND METAL CONCENTRATION DATA

Sample	Metals (mg/Kg)					
	Copper	Zinc	Cadmium	Lead	Calcium	Magneseum
Slurry filtrate[1]	4.7	1.8	1.2	BDL[2]	17.4	BDL
Slurry Solids	35.2	94.2	1.8	6.4	81889.7	9548.0
Paste Material	66.4	123.7	1.6	8.4	84702.5	7877.2
Cuttings	36.4	111.2	1.4	6.3	75802.4	6416.4

[1] In mg/L
[2] Below detectable limit

Composts	Parameters				
	pH	Zinc (mg/Kg)	Copper (mg/Kg)	Cadmium (mg/Kg)	Lead (mg/Kg)
WSU	7.96	19.0	4.1	1.3	1.3
EKO	7.14	134.1	41.2	1.4	3.7